VALVE, ACTUATOR AND CONTROL SYSTEM THEREFOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates to a system of a hydraulic actuator for operating a valve between open and closed positions and the control system used to regulate the operation of the actuator. This system is particularly suited for operation of ball valves used in the oil and gas industry. These ball valves are typically used in gas pipelines to control the flow of gas through the pipeline. The actuator of the present invention uses gas pressure from the pipeline to power the actuator. In the event gas pressure from the pipeline is unavailable or inaccessible, a pair of manual hand pumps are incorporated to allow operation of the actuator and valve.

[0002] Prior actuators utilizing the gas pressure of the pipeline as a power source typically have a double acting piston upon which the gas acts to drive the actuator and hence the valve to be opened or closed. These actuators have vented the gas pressure from one side of the double acting piston as gas pressure is applied to the other side of the piston. This venting is necessary to ensure that equal pressure is not acting on both sides of the piston simultaneously. In this event, the force acting on both sides of the piston would balance and the actuator would fail to operate or be "pressure locked" as commonly referred to in the industry.

[0003] As a result of the need to vent each side of the actuator piston to ensure proper operation, the gas pressure is usually vented to atmosphere. This gas is not a pure gas but in fact has hydrocarbon liquids entrained in the gas, known as condensate in the industry. When this venting to atmosphere occurs, the hydrocarbon liquid condensate condenses and becomes a sticky, unsightly oily residue on the ground adjacent the valve and actuator. In recent years this venting to the atmosphere of the gas has raised environmental concerns due to possible contamination of the ground and groundwater by this oily residue.

[0004] Another concern with prior valve, actuator and control system assemblies has been the interface and operation of the manual hand pumps that are required to operate the actuator and valve when gas pressure from the pipeline is not available. This may occur during new installations when the pipeline has not been filled with gas yet and

opening or closing of the valve is needed. Other times when maintenance is to be performed on the valve or actuator, the pipeline must be bled of gas pressure as a safety precaution. When it is desired to operate the valve prior to subsequent pressurization of the pipeline, the ability to operate the valve and actuator manually is required. Prior valve, actuator and control system assemblies have had problems in their design and operation that allowed possible scenarios in which pressurization of the pipeline and thus the actuator, could result in inadvertent operation of the actuator while manual operation of the actuator was occurring and possible injury to an operator. It is therefore desirable to have a valve, actuator and control system assembly that allows minimizing the size of the actuator and operation of the control system in a manual mode that automatically prevents accidental operation by pipeline pressure. The valve, actuator and control system of the present invention offers such novel features.

2. Description of Related Art

[0005] U. S. Patent No. 6,231,027 B1 to G. S. Baker et al. shows a valve actuator that utilizes a variable helix angle to generate greater operating torque near the end of its travel.

[0006] A subsea rotary adjusting device for valves is disclosed in PCT International Publication No. WO 02/37008 A1 to K. Biester et al. The device utilizes a helical slot in a sleeve to translate axial motion into rotary motion.

[0007] PCT International Publication No. WO 03/025428 A1 to K. Biester et al. shows a travel multiplying device utilizing three concentric pipes with spherical linking elements to magnify relative longitudinal motion between adjacent pipes.

SUMMARY OF THE INVENTION

[0008] The present invention relates to a system of a hydraulic actuator for operating a valve between open and closed positions, the valve itself and the control system used to regulate the operation of the actuator. The valve is installed in a gas pipeline, typically used in the oil and gas industry, to control flow through the pipeline. The actuator of the present invention uses gas pressure from the pipeline to power the actuator.

[0009] The valve is a ball valve that uses a spherically shaped ball to control fluid flow through the valve. End flanges are welded to the outer body shell for connection to mating

pipeline connections. A quarter turn of the ball moves the valve from open to closed positions. The valve actuator is mounted on top of the valve and rotates the ball between open and closed positions when operated.

[0010] The valve actuator is comprised of a lower actuator housing with a bore therethrough to which an actuator cylinder housing having a counterbore is secured in sealing engagement to a first end of the lower actuator housing. A lower actuator plate with a bore is secured to the second end of the lower actuator housing. A helix sleeve is secured within the lower actuator housing bore and seals therein. The helix sleeve has a pair of helical slots cut in its wall and a reduced diameter bore on one end. An actuator drive shaft extends between the actuator cylinder housing bore and the reduced diameter bore of the helix sleeve and seals within these bores and is axially restrained between them.

[0011] An actuator piston sleeve is sealingly disposed in the annulus between the actuator drive shaft and the actuator cylinder housing with the actuator piston sleeve axially moveable in response to hydraulic pressure. The actuator piston sleeve has a reduced diameter portion extending into the annulus between the actuator drive shaft and the helix sleeve with the reduced diameter portion of the actuator piston sleeve sealing on the actuator drive shaft and the reduced diameter portion of the actuator piston sleeve having a pair of axially disposed slots. A pair of rollers are attached to the reduced diameter portion of the actuator piston sleeve and engage the helical slots in the helix sleeve and a second pair of rollers are attached to the actuator drive shaft and engage the axially disposed slots in the reduced diameter portion of the actuator piston sleeve such that reciprocation of the actuator piston sleeve causes rotation of the actuator drive shaft.

[0012] The hydraulic control system for the valve actuator is comprised of open and close circuits with each circuit including a control valve, a pair of pilot operated valves and a fluid supply tank for supplying control fluid under pressure to the appropriate actuator function. The outlet port of the second pilot operated valve in each circuit is connected to an exhaust orifice valve. The control valve in each circuit receives pressurized gas from an outlet on the pipeline and directs this pressurized gas to the appropriate tank when the control valve is operated. This pressurized gas is also used to operate the pilot operated valves to control venting of pressure from one tank while the other is being pressurized to

prevent pressure lock and allow equalization of pressure between the tanks after the valve is moved to its fully open or closed position.

[0013] A principal object of the present invention is to provide a valve, actuator and control system that allows minimizing the size of the actuator and operation of the control system in a manual mode that automatically prevents accidental operation by pipeline pressure.

[0014] Another object of the present invention is to provide a valve, actuator and control system that is modular in construction to allow adaptation to different valve sizes.

[0015] A final object of the present invention is to provide a valve, actuator and control system for gas pipelines that minimizes the condensate vented to the atmosphere during operation.

[0016] These with other objects and advantages of the present invention are pointed out with specificness in the claims annexed hereto and form a part of this disclosure. A full and complete understanding of the invention may be had by reference to the accompanying drawings and description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] These and other objects and advantages of the present invention are set forth below and further made clear by reference to the drawings, wherein:

[0018] FIGURE 1 comprises a perspective view of a system for controlling fluid flow through a pipeline including valve, actuator and control system assembled together. FIGURE 2 is a perspective view from the opposite side with partial sectional views of valve 12 and actuator 14 to show the main components. sectional view of a wellhead system with the right half of the view showing a combination of standard casing hangers and packoff assemblies and the left half of the view showing a combination of casing hangers and packoff assemblies for emergency situations in which the casing sticks in the well bore while being lowered into position.

[0019] FIGURE 2 comprises a perspective view from the opposite side with partial sectional views of the valve and actuator to show the main components.

[0020] FIGURE 3 comprises a sectional view of the valve actuator in the valve closed position.

[0021] FIGURE 4 comprises a sectional view of the valve actuator in the valve open position.

[0022] FIGURE 5 comprises a perspective view of the actuator and actuation of the helix sleeve therein.

[0023] FIGURE 6 comprises a schematic view of the control system.

[0024] FIGURE 7 comprises a view of the flow diagram of the control system.

[0025] FIGURE 8 comprises a sectional view of the fluid supply tanks and manually operated valves mounted thereon of the control system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] With reference to the drawings, and particularly to **FIGURE 1** a perspective view of a system **10** for controlling fluid flow through a pipeline including valve **12**, actuator **14** and control system **16** assembled together is shown. **FIGURE 2** is a perspective view from the opposite side with partial sectional views of valve **12** and actuator **14** to show the main components. Valve **12** is a ball valve of the type commonly used in the oil and gas industry, with a welded body **18** and end flanges **20** for installing valve **12** into a pipeline (not shown) through which valve **12** will control the flow of oil and gas. Valve **12** includes a flow controlling member or ball **22**, disposed in welded body **18**, with a bore **24** therethrough. Seal elements **26** in welded body **18** seal against ball **22**. Rotation of ball **22** a quarter turn by actuator **14** closes valve **12**.

[0027] Actuator **14** includes lower actuator housing **28** to which actuator cylinder housing **30** is secured. Helix sleeve **32** is disposed within lower actuator housing **28** and actuator piston sleeve **34** is positioned within helix sleeve **32**. Details of construction of actuator **14** and actuation of helix sleeve **32** are shown in sectional views **FIGURES 3** and **4** and perspective view **FIGURE 5**. **FIGURE 3** shows actuator **14** in the position of valve **12** being closed and **FIGURE 4** shows actuator **14** in the position of valve **12** being open. Lower actuator housing **28** has bore **36** extending therethrough. Actuator cylinder housing **30** has counter bore **38** extending therein and is secured to lower actuator housing **28** by suitable securing means as studs **40** and nuts **42**. Bore **36** and counterbore **38** are axially coincident. Lower actuator housing **28** is sealed against actuator cylinder housing **30** by

sealing means in the form of seal ring **44**.

[0028] Lower actuator plate **46** and guide sleeve **48** are secured to the opposite end of lower actuator housing **28** by suitable securing means as studs **50** and nuts **52**. Lower actuator plate **46** and guide sleeve **48** have bores **54** and **56** therethrough. Helix sleeve **32** is secured within lower actuator housing **28** by lower actuator plate **46** and actuator cylinder housing **30**. Seal ring **58** seals helix sleeve **32** to lower actuator housing **28** while first and second securing means in the form of anti-rotation or dowel pins **60** and **62** between helix sleeve **32** and lower actuator housing **28** prevent helix sleeve **32** from rotational movement with respect to lower actuator housing **28** and actuator cylinder housing **30**.

[0029] Helix sleeve **32** includes reduced diameter bore **64** on the end adjacent lower actuator plate **46**. Actuator drive shaft **66** is a cylindrical member that extends between bore **68** in actuator cylinder housing **30** and reduced diameter bore **64** of helix sleeve **32**. Actuator drive shaft **66** is sealed in bores **64** and **68** by seal rings **70** and **72**, respectively. Bore **68** is axially coincident with counter bore **38** as is stepped bore **74** in actuator cylinder housing **30**. Adjacent reduced diameter bore **64** is stepped bore **76** in helix sleeve **32**. Stepped bores **74** and **76** act to axially restrain actuator drive shaft **66** when actuator **12** is assembled.

[0030] Actuator piston sleeve **34** is sealingly disposed in the annulus between actuator drive shaft **66** and counter bore **38** of actuator cylinder housing **30**. Seal rings **80** and **82** seal actuator piston sleeve **34** to actuator drive shaft **66** and counter bore **38** of actuator cylinder housing **30**. Actuator piston sleeve **34** has a reduced diameter portion **84** that extends into the annulus between actuator drive shaft **66** and helix sleeve **32** and seals on actuator drive shaft **66** with seal ring **86**. Reduced diameter portion **84** of actuator piston sleeve **34** has a pair of axially disposed slots **88** formed therein. An actuation means in the form of a pair of rollers **90** are secured to actuator drive shaft **66** at approximately its middle and rollers **90** engage axially disposed slots **88** for purposes to be described hereinafter. Helix sleeve **32** includes a pair of helical slots **92** formed in its wall. As best seen in **FIGURE 5**, a second actuation means in the form of a pair of rollers **94** are secured to the lower end of reduced diameter portion **84** of actuator piston sleeve **34** at

right angle to axially disposed slots **88** and engage helical slots **92** in helix sleeve **32**.

[0031] First end **96** of actuator drive shaft **66** extends beyond stepped bore **74** and includes indicator means or slot **98** formed thereon to indicate the rotational position of actuator drive shaft **66**. Opposite or second end **100** of actuator drive shaft **66** extends beyond stepped bore **76** and includes engaging means in the form of male spline **102** formed thereon. Valve closure adapter **104** engages spline **102** and connects to valve **12** with spline **106** to transmit the torque generated by actuator **14**. Ports **108** and **110** in actuator cylinder housing **30** allow pressurized hydraulic fluid, supplied by control system **16** in a manner to be described hereinafter, to operate actuator **12** in the following manner.

[0032] As noted above, **FIGURE 3** shows actuator **14** in the position with valve **12** closed. Actuator piston sleeve **34** is at the bottom of its stroke. When it is desired to open valve **12**, pressurized hydraulic fluid to supplied to port **108** while port **110** is vented. The pressurized hydraulic fluid acts on the underside of actuator piston sleeve **34** against the annular piston area defined by seals **80** and **82** while seals **44**, **58** and **70** maintain pressure in lower actuator housing **28**. As actuator piston sleeve **34** is urged upwardly, slots **88** move axially over rollers **90** on actuator drive shaft **66**. Simultaneously, rollers **94** on reduced diameter portion **84** of actuator piston sleeve **34** are engaging helical slots **92** of helix sleeve **32**. As helix sleeve **32** is anti-rotated with respect to lower actuator housing **28** by pins **60** and **62**, rollers **94** are forced to move along helical slots **92** of helix sleeve **32** which causes actuator piston sleeve **34** to rotate with respect lower actuator housing **28**. This rotation of lower actuator housing **28** is transmitted through axial slots **88** and rollers **90** to actuator drive shaft **66**, thus rotating valve closure adapter **104** and valve **12** through splines **106** to move valve **12** to its open position shown in **FIGURE 4**. When it is desired to close valve **12**, pressurized hydraulic fluid is supplied to port **110** while port **108** is vented to reverse the direction of rotation.

[0033] Operation of valve **12** and actuator **14** is regulated by control system **16** which is shown in schematic form in **FIGURE 6** and in flow diagram form in **FIGURE 7**. **FIGURE 6** shows control system **16** includes first and second control valves **200** and **202** controlling operation of actuator **14** through first through fourth pilot operated valves **204**, **206**, **208**

and **210**. Valves **200** - **210** control hydraulic fluid flow from first and second actuator fluid supply tanks **212** and **214** to the open and close ports **108** and **110** of actuator **14**. Control system **16** includes a fluid pressure source **216** which is gas pressure supplied from the pipeline (not shown) through which valve **12** and actuator **14** control gas flow. Control system **16** further includes a normally open double pilot operated two way valve **218** to equalize gas pressure between tanks **212** and **214** which is bled to atmosphere through exhaust orifice valve **220.** First and second actuator fluid supply tanks **212** and **214** have hydraulic fluid **222** in their lower portion which is the pressurized fluid supplied to actuator **14**. Hydraulic fluid **222** is pressurized by the action of pipeline gas pressure acting thereon.

[0034] The flow diagram of **FIGURE 7** shows details of the construction of the components of control system **16** and the gas and hydraulic fluid flow therebetween. Control system **16** is divided into first and second control circuits **224** and **226**. First control circuit **224** acts to supply hydraulic fluid **222** to port **108** and operate actuator **14** to close valve **12**, while second control circuit **226** acts in reverse to supply hydraulic fluid **222** to port **110** and operate actuator **14** to open valve **12**. Additionally, control system **16** includes manually operated hand pumps **228** and **230** mounted on first and second actuator fluid supply tanks **212** and **214**, respectively, for purposes to be described hereinafter.

[0035] First and second control valves **200** and **202** are manually operated valves including inlet port **232**, outlet port **234** and vent port **236**. In the closed position, fluid flow between inlet port **232** and outlet port **234** is blocked while outlet port **234** is connected to vent port **236**. In the open or operating position, fluid flows between inlet port **232** and outlet port **234** while vent port **236** is blocked. First through fourth pilot operated valves **204**, **206**, **208** and **210** are two way normally closed pilot operated valves including inlet port **238**, outlet port **240** and pilot port **242**. In the closed position, i.e., no pressure supplied to pilot port **242**, fluid flow between inlet port **238** and outlet port **240** is blocked. In the open, i.e., pilot operated position, pilot pressure supplied to pilot port **242** allows fluid flow between inlet port **238** and outlet port **240**. First and second control valves **200** and **202** and first through fourth pilot operated valves **204**, **206**, **208** and **210** are mounted

in a manifold block (not shown) in a manner well known to those of ordinary skill in the art Control system **16** also includes double pilot operated two way valve **218** with pilot pressures supplied from first and second control circuits **224** and **226**.

[0036] First and second actuator fluid supply tanks **212** and **214** are identical in construction. Tanks **212** and **214** are supplied with hydraulic fluid **222** partially filling the tanks. Baffles **246** are positioned in tanks **212** and **214** to aid in maintaining separation between the pressurized gas supplied by the pipeline and hydraulic fluid **222**. Manually operated hand pumps **228** and **230** and mounted on tanks **212** and **214**, respectively, and each pump **228** and **230** includes shuttle valve **252** mounted thereon.

[0037] Details of construction and operation of tanks **212** and **214**, pumps **228** and **230** and shuttle valves **252** are shown in **FIGURE 8**. Only the description of tank **212**, pump **228** and shuttle valve **252** are given as tank **214** and pump **230** are identical thereto. Pump **228** is mounted to tank **212** by double flange **254** with pump **248** extending into tank **212** and immersed in hydraulic fluid **222**. Pump **228** is of the "sucker rod" type well known to those of ordinary skill in the art with hydraulic fluid **222** being drawn into pump **228** through spring loaded ball **256** when handle **258** is stroked away from tank **212**. Hydraulic fluid **222** is pressurized in pump **228** as handle **258** is stroked toward tank **212** and unseats spring loaded ball **260** and is directed out port **262** to shuttle valve **252**. Shuttle valve **252** shuttles between a position in which fluid from port **262** flows through shuttle valve **252** to outlet port **264** and to either port **108** or **110**, depending on which tank is being used, and a second position in which pressurized hydraulic fluid **222** is received into port **266** and to outlet port **264**. Pressurized hydraulic fluid **222** is supplied to port **266** through a by pass passage **268** in double flange **254**. Pressurized hydraulic fluid **222** is only supplied to by pass passage **268** when tank **212** is pressurized by gas supplied through first and second control circuits **224** and **226**.

[0038] A typical sequence of operation for control system **16** would be as follows assuming valve **12** is in the open position and it is desired to close valve **12**. Referring to the flow diagram of **FIGURE 7**, first control circuit **224**, i.e., the "close" circuit, is operated by depressing first control valve **200**. This operation causes the following functions to happen as pressurized gas is supplied:

(*i*) directs pressurized gas pressure to pilot operated normally open valve **218** to equalize pressure between actuator open fluid supply tank **214** and actuator close fluid supply tank **212**;

(*ii*) directs pressurized gas pressure from outlet port **234** of first control circuit control valve **200** to pilot port **242** of first pilot operated valve **204** of valve closing first control circuit **224** to operate first pilot operated valve **204** and allow pressurized gas pressure to pressurize hydraulic fluid **222** in actuator close fluid supply tank **212** and supply pressurized hydraulic fluid **222** through by pass passage **268**, through port **266** to outlet port **264** and thence to port **108** (close port) of actuator **14** to close valve **12**; and,

(*iii*) directs pressurized gas pressure from outlet port **240** of first pilot operated valve **204** of first control circuit **224** to pilot port **242** of fourth pilot operated valve **210** of valve opening second control circuit **226** to operate fourth pilot operated valve **210** and vent pressurized gas pressure from actuator open fluid supply tank **214** through exhaust orifice valve **220**. Closure of first control circuit control valve **200** to a closed position and operation of second control circuit control valve **202** to an open position results in the same operations described above but in reverse order to open valve **12**.

[0039] If pressurized gas pressure is not available as in the case of a break in the pipeline and it is necessary to close valve **12**, manually operated hand pump **228** on actuator close fluid supply tank **212** may be operated. Such operation pressurizes hydraulic fluid **222** in tank **212** as described above and directs such fluid **222** through port **262** to port **108** of actuator **14** to close valve **12**. Note that such operation causes shuttle valve **252** to shift and block port **264** and automatically lock out gas powered control circuit **224**, if any residual pressure is present. Should opening of valve **12** be desired, pump **230** in actuator open fluid supply tank **214** may be operated to reverse operation and open valve **12**.

[0040] The construction of our system for controlling fluid flow through a pipeline including valve, actuator and control system will be readily understood from the foregoing description and it will be seen that we have provided a system that allows minimizing the size of the actuator and operation of the control system in a manual mode that

automatically prevents accidental operation by pipeline pressure while minimizing the condensate vented to the atmosphere during operation. Furthermore, while the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalent alterations and modifications, and is limited only by the scope of the appended claims.